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MATERIALS FOR NON-METALLIC DRIVING BANDS. PART I. FOREWORD. PART II (A). THE PROPERTIES REQUIRED FROM A DRIVING BAND MATERIAL (U)

DIRECTORATE OF WEAPON RESEARCH (DEFENCE) LONDON ...

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MATERIALS FOR NON-METALLIC DRIVING BANDS

PART I

FOREWORD

The aim of the review is to assemble the facts and experience relevant to the problem, to record the opinions of the Panel about the difficulties which have to be faced, to suggest ways in which they might be overcome, and to describe the research programme which is being sponsored by the Panel. The fact that a lack of sound and communicable knowledge is frequently disclosed reflects the present situation in the plastics field where 'know-how' is much more common than tables of reliable design data.

The review is planned in four parts:

Part I		Foreword.
Part II	(a)	The properties required of a driving band material
	(b)	Assessment of the suitability of materials for Service non-metallic driving bands.
Part III	(a)	An appraisal of available plastic materials
	(b)	Nylon and its use for bands for projectiles (already issued as WR(D)6/52)
Part IV		The basic aspects of the problem of the material.

To simplify discussion and the reading of this review and other reports which may be issued by the Panel it has been agreed to define a few terms which are in constant use. There is no precedent for the usage proposed.

The terms are:-

(i) Plastic: any non-metallic material: some which may be considered for bands would not fit the normal meaning of this word.

(ii) Reinforced Plastic: one incorporating fibrous or the like material (e.g. glass, cotton, asbestos etc. fibre).

(iii) Raw Powder: powder as delivered by the manufacturer to the moulder.

(iv) Treated Powder: raw powder after it had been treated in any way by the moulder, e.g. dried.

(v) Ring: a ring shaped moulding as it leaves the machine either as a separate article or in position on a projectile.

(vi) Treated Ring: a ring after treatment, e.g. boiling, but before machining.

(vii) Part Machined Ring: a treated ring after part machining.

(viii) Band: (a) a fully machine treated ring
(b) a driving band, a centering band.

The problems with regard to the material for centering rings and sabots are not identical with those for driving bands and although many of the problems are common, it was considered better to limit this review to materials for driving bands and to cover the question of materials for centering rings and sabots separately.

/INTRODUCTION

INTRODUCTION

1. The need for non-metallic driving bands

Research and experience have shown that copper driving bands, of any design, are no longer capable of meeting all requirements, and that even under conditions where they function satisfactorily in their prime purpose of imparting spin, they have some undesirable characteristics. If the muzzle velocity of a gun is above 3000 ft./sec., a copper driving band tends to fail in centering the projectile and groove marking and muzzle wear occur. Under more severe conditions the copper band is incapable of imparting full spin to the projectile. Copper driving bands exert a high radial pressure on the gun bore and play an important part in the erosion process; they are also responsible for such ballistic effects as "downward crash". Copper bands have been found to cause deformation of the lands and bore expansion in hot gun barrels and on this account restrict the temperature at which the barrel can operate in automatic fire.

Other types of driving band have been developed by the A.R.E. which are free from many of the shortcomings and disadvantages of copper bands. These are steel skirt driving hands and non-metallic driving bands. Sintered iron driving bands, although free from the limitations of copper bands have, at present, the severe disadvantage of promoting general abrasive wear of the gun bore and until this is overcome they cannot be regarded as satisfactory; they also lack mechanical strength to withstand high rates of spin.

Steel skirt driving bands have been shown to be suitable for Service projectiles with the exception of those with streamline bases; they appear to have no disadvantages when compared with copper bands, and are superior for centering the projectile and induce less barrel wear in single shot firings. They are also superior for maintenance of ballistics. No data are as yet available regarding the effect of firing skirt banded projectiles in hot barrels.

In the A.R.E. research work on non-metallic driving bands, ebonite, grey fibre and nylon bands have shown considerable promise. Experimentally they function excellently at all velocities; they are at least equal to steel skirt driving bands in maintenance of ballistics and are likely to be superior in their effect on erosion when used in automatic fire and with chromium plated barrels. Their lightness is an important advantage in A.P.D.S. projectiles.

The muzzle velocites of a number of new guns, both under development and projected, are above the range for which copper driving bands are adequate. There is therefore a definite requirement for a new type of driving band, and from the functioning aspect, non-metallic driving bands appear to offer a very satisfactory solution. Non-metallic driving bands are not however, the only solution in view; steel skirt driving bands are strong competitors though as regards barrel wear they seem likely to be rather less advantageous. Sintered materials also show some promise.

2. Plastics materials

The quantity of plastics produced is of a lower order than that of the commoner metals and alloys. Production cannot easily be stepped up because the raw materials have other uses as well as for plastics and the plant needed is neither simple nor cheap to produce.

/The application

The application of plastics to engineering purposes is in its infancy. So far there has been no real buyer pressure to obtain materials to close specification, and suitable inspection techniques have either not been worked out or have not been applied commercially.

The field of plastics covers a very wide range of materials and properties, and the best choice of a material for any specific application can only be made with a full knowledge of the performance and properties required. In general, also, it is necessary to accept certain limitations of the chosen materials and design with these factors in mind. There are two main groups of plastics: thermo-setting and thermo-plastic. Thermo-setting plastics are in general non-softening, rigid materials which tend to be brittle. In order to improve their properties they are normally reinforced with fillers, more usually fibrous. Assuming suitable design and choice of material, thermo-setting plastics may be considered to be roughly equivalent on a weight basis to light alloys. Temperature susceptibility, thermal expansion, mechanical strengths per unit weight, can be of the same order, while the better dimensional stability of light alloys to moisture may be offset against their much easier corrodibility.

Thermo-plastics range from materials which are brittle at ordinary temperatures to those which are rubbery. Softening points range from 400°C downwards with the majority in the range 80 - 100°C. It should be appreciated that this latter group is the most popular because such materials can be processed more readily with standard equipment. The preparation and utilisation of higher melting materials is not impossible but the attendant problems which arise in processing militate against their commercial development unless they have certain outstanding properties.

Thermo-plastic mouldings are prepared under high pressure and in the great majority of cases considerable stress develops during cooling from the mould. The relaxation of these stresses leads to one type of dimensional instability. Similarly the application of a stress to a thermo-plastic causes creep or cold flow with consequent dimensional changes or in the case of bands possibly functioning problems. Thermal expansion is high, of the order of ten times that of mild steel or three times that of light alloys. In addition, certain thermo-plastics absorb water and further dimensional and mechanical changes arise from this cause.

Commercially, the attraction of thermo-plastics has been their ease of processing and attractive decorative appearance, and consequently few attempts have been made to overcome the limitations mentioned above. It is clear, however, that by reinforcement with suitable fillers the effective thermal expansion may be reduced and in addition the impact properties improved. Appropriate heat treatment can reduce internal stress, and cold flow could be tackled from the design angle, but it must be emphasised that this is as yet a comparatively unexplored field, and the collection of a large amount of basic data would be necessary before any serious attempt could be made to choose a suitable material on a basis of known physical and mechanical properties.

There is a general lack of research facilities for work on plastics both in industry and in Government establishments and there is no co-ordinating Research Association.

The standard climatic trials for Service stores are not appropriate to plastics and C.S.R.'s ranges are not equipped with climatic conditioning plant needed for comprehensive firing tests of plastic driving bands.

/PART II(a)

MATERIALS FOR NON-METALLIC DRIVING BANDS

PART II (a)

THE PROPERTIES REQUIRED OF A DRIVING BAND MATERIAL

1. Functional requirements of a driving band

The Essential functional requirements of a driving band are

(i) to impart spin to the projectile

(ii) to centre the rear end of the projectile in the bore

and in certain cases

(iii) to obturate,

and

(iv) to remain on the projectile after ejection.

The Conditions under which these requirements must be met are

(i) in new and worn guns,

(ii) throughout the appropriate Service operating temperature range,

and in certain cases

(iii) after loading in hot guns.

Desirable characteristics of a driving band are

(i) minimum enhancement of erosion,

(ii) minimum abrasive wear of gun bore,

(iii) minimum radial pressure on gun bore consistent with obturation,

(iv) low specific gravity in relation to strength, and

(v) as favourable as possible for accuracy.

2. Operational requirements of a driving band

The operational requirements of a driving band are

(a) ability to withstand, without unacceptable degradation in properties

(i) storage conditions of temperature (as defined in the Service requirements), humidity, tropical conditions, etc.,

(ii) rough usage and other handling conditions in the field,

(b) compatibility with

(i) the material of the projectile with which it is in contact, and

(ii) The propellant in certain cases.

/3.

3. Manufacturing requirements of a driving band

The manufacturing requirements of a driving band are

(i) that the band material is in adequate and satisfactory supply, and

(ii) that the band can be mass produced, assembled on the shell and satisfactorily inspected.

4. Interpretation of Functional and other requirements as physical and chemical properties.

To impart spin to the projectile, the driving band must become engraved and engage with the rifling of the gun. In a new gun the band is engraved by simple deformation, or swaging, under compressive forces. The amount of deformation is quite large; under the lands of the rifling the strain can be as much as 50% and is rarely less than 25%. The strain rate, however, is not high being about 1000 sec^{-1}.

In a worn gun engraving is a more complex process. The projectile may have travelled some distance before the driving band makes effective contact with the rifling, it must then acquire rapidly the rotational velocity appropriate to its forward velocity and the twist of rifling and while this is being achieved there will be 'slip', or relative movement between the rifling profile and the band. Engraving is thus accompanied by a machining action by the rifling which may remove material from the surface of the band. Some loss of material is acceptable provided that the band eventually becomes properly engraved. The ability of the band material to withstand these conditions is related to its shear strength and shock resistance.

When the driving band is fully engraved, it requires adequate shear strength to transmit the necessary torque to the projectile and it must also be able to sustain the contact pressure on the driving surface of the rifling lands which this torque implies. The shear strength required is quite modest - only a few tons per sq.inch - but the contact pressure may be considerable if the number of rifling grooves is low - 15 tons per sq.inch or more. But the material is normally closely confined (i.e. fills the grooves) when called upon to sustain this high pressure and the significant property is the flow pressure rather than compressive strength.

It is necessary for the driving band to retain its engraved shape and strength during its passage up the bore; this implies a resistance to abrasion by the driving edges of the lands, and a combination of frictional and thermal properties so that frictional heating does not impair its performance: a low coefficient of friction and low thermal conductivity are desirable but critical conditions are only known to occur with metals of high thermal conductivity such as copper, brass and aluminium.

In order to maintain the projectile centred in the bore, the band must have adequate compressive strength, which is not impaired by frictional heating during the passage of the projectile up the bore. Good obturation is a most important factor in ensuring proper centering. In some cases a sealing ring may be provided for obturation. The suitability of a driving band for this function is mainly a question of design, though adequate and maintained compressive strength to give a radial band pressure in excess of the gas pressure is desirable.

For the driving band to remain on the projectile after leaving the muzzle of the gun it must have adequate tensile strength to resist the centrifugal forces due to the rotation of the projectile. The strength

/required

required is to a large extent determined by the muzzle velocity and the twist of rifling, though design may have an appreciable effect. Taking the case of the new A.A. guns, the requirement is equivalent to a tensile strength of about 1.2 tons per sq.inch (assuming the density of the material to be 1.2 gms/c.c.).

Compliance with Service requirements necessitates that the properties discussed above must be found at all temperatures within the appropriate operating range, and, in addition, must not be impaired by storage at temperatures within the appropriate storage range. These operating and storage temperature ranges are as follows.

Temperature limits in degrees F

Category		Operating	Storage
War Office	Normal	125 to -25	160 to -50
"	Extreme	down to -65	down to -80
"	Universal	125 to -65	160 to -80
Admiralty	Open Mtgs.	120 to -30	-
"	Enclosed mtgs.	100 to 0	-
"	2 months	"	140 to -30
"	6 months	"	0
"	Life of propellant	"	120

In the case of certain weapons, in particular A/T guns, it is necessary to take into account the so called 'hot gun condition'. This arises when immediately after the gun has fired a number of rounds rapidly it is necessary to load a round which may not be fired immediately but which must function correctly when fired. It is difficult to specify this condition except as a temperature which the band material must withstand for a short time without degradation of functioning and it is usual to quote the 'cook-off' temperatures of the propellant for this purpose, i.e. 320°F. The temperature of the bore surface adjacent to the driving band in the loaded position can be above this temperature before actual cook-off occurs, but there is a compensating factor in that the band can only absorb heat slowly and the temperature of the bore surface will fall fairly rapidly due to conduction of heat to cooler parts of the gun barrel.

Coming now to desirable characteristics, the driving band material should have the minimum hardness consistent with the necessary shear strength, and freedom from abrasive ingredients so as to avoid damaging the bore and protective bore coatings. A low specific gravity minimises wastage of energy, and damage from pieces of band if discarded at the muzzle.

Variability of assymmetry in the external shape of the driving band after ejection may cause loss of accuracy. These may be due to irregular deformation at engraving - a question of design - or to assymmetric deformation of the band under the centrifugal forces after ejection. Tendency to the latter is enhanced by the comparatively large strains corresponding to a low value of Young's modulus for the band material.

Storage temperature conditions have already been referred to. To these must be added humidity conditions, which are given as a maximum of 100% between 32°F and 95°F (WOPS No.70 second Revise, dated February, 1949; see also O.B. Proc. No. Q.6137 (Sp)). The only accepted humidity/temperature cycling tests at present are the ISAT (a) or (b) (O.B. Proc. No.34,330) although these have shortcomings where materials of intrinsic (though low) water vapour permeability are concerned (e.g. nylon). To withstand these conditions the band material requires to be stable chemically over the temperature range, to suffer no permanent effects from humidity likely to be encountered within this same range, to be resistant to fungoid growths and attack by insects. In storage not only must the strength of the band be maintained but dimensional changes must not exceed the limits which can be tolerated by design.

/Compatibility

Compatibility with propellant has two aspects: the effect of the band material on the stability of the propellant and the effect of the propellant vapours on the physical and chemical properties of the band material. Presence of nitro glycerine in the vapour from double-base propellants is the main cause of trouble though nitrogenous decomposition products are also present in small quantities. With single base propellants the vapour is mostly that of the solvents used in manufacture - ether and alcohol.

5. Summary of properties required of a driving band material

(a) Properties which are essential in all applications

within the temperature range of 125°F to -25°F

(i) medium shock resistance,
(ii) high degree of deformability
(iii) moderate shear and compressive strength.

and within the temperature range of 160°F to -80°F.

(iv) chemical stability.

(b) Additional properties which are essential in some applications.

(i) moderate tensile strength within the temperature range of 125°F to -25°F
(ii) an adequate reserve of strength at 350°F
(iii) ability to resist propellant vapour without serious degradation in properties and
(iv) no adverse effect on the stability of the propellant

(c) Desirable properties are

(i) minimum hardness consistent with necessary shear strength
(ii) freedom from abrasive ingredients
(iii) low specific gravity in relation to strength
(iv) resistance to micro-biological attack
(v) high value of Young's Modulus.

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